CHAPTER 12 PRACTICE EXERCISES

SECTION I MULTIPLE CHOICE

1. A current of 3.2 A flows in a segment of copper wire. The number of electrons crossing the cross-sectional area of the wire every second is most nearly

   (A) 3.2 (B) 2×10^{19} (C) 2×10^{-19} (D) 3.2×10^{19} (E) 3.2×10^{-19}

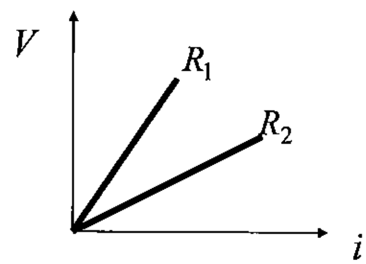

Figure 21

2. Resistors R_1 and R_2 have voltage vs. current graphs as shown in figure 21. The graph that best represents the voltage vs. current graphs for the equivalent series and parallel resistances R_s and R_p of the two is

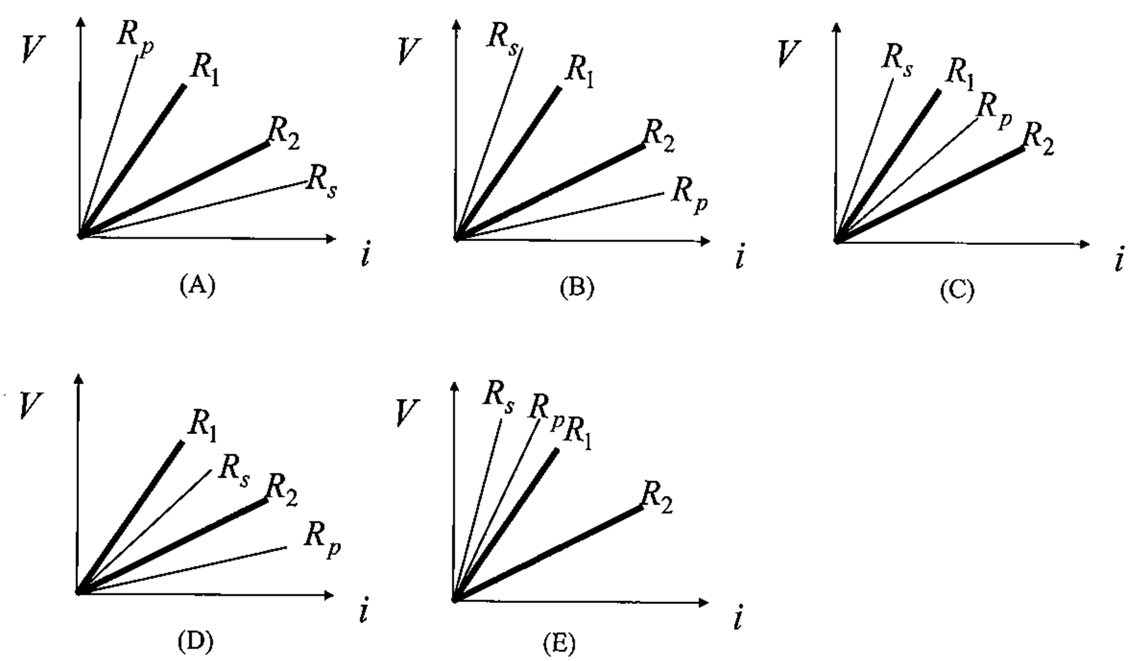

Figure 22

3. A cylindrical length L of conducting material with cross-sectional area A has a resistivity ρ. Another material with twice the resistivity is to be drawn to a length $2L$ to form a resistor with the same resistance as the original. Its cross-sectional area must be

(A) A (B) $2A$ (C) $3A$ (D) $4A$ (E) $\frac{1}{4}A$

Questions 4 and 5

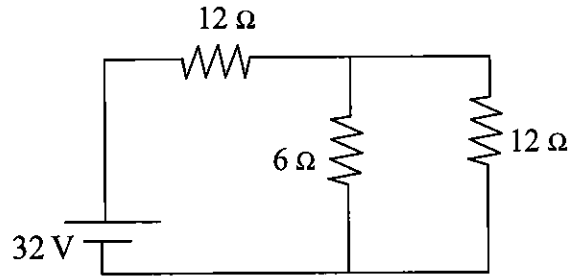

Figure 23

4. The voltage drop across the 6 Ω resistor is most nearly

(A) 16 V (B) 10.7 V (C) 8 V (D) 32 V (E) 24 V

5. The electrical energy converted to thermal energy in the resistors in 10 seconds is

(A) 240 J (B) 24 J (C) 64 J (D) 1,000 J (E) 640 J

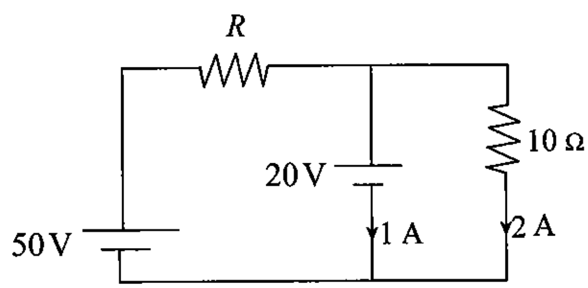

Figure 24

6. The circuit shown in the figure carries 1 A and 2 A in two branches as shown. The value of R is most nearly

(A) 10 Ω (B) 20 Ω (C) 30 Ω (D) 40 Ω (E) 50 Ω

7. Which of the following statements is true?
   I. The terminal voltage of a battery depends on the resistance connected to the terminals.
   II. The terminal voltage of a battery is always less than the ideal voltage of the battery.
   III. The terminal voltage of a battery is always greater than the ideal voltage of the battery.

   (A) none of the above (B) I only (C) II only (D) III only (E) I and II only

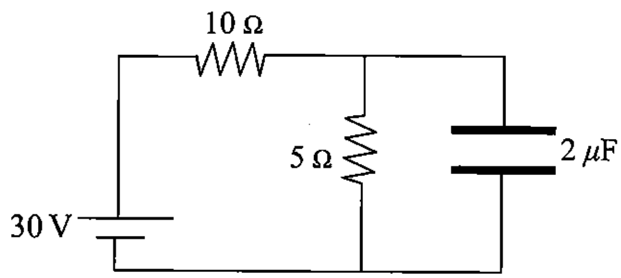

Figure 25

8. The circuit shown in the figure has been connected for a long time. The charge on one of the capacitor plates is

   (A) 60 μC (B) 20 μC (C) 2 μC (D) 40 μC (E) 30 μC

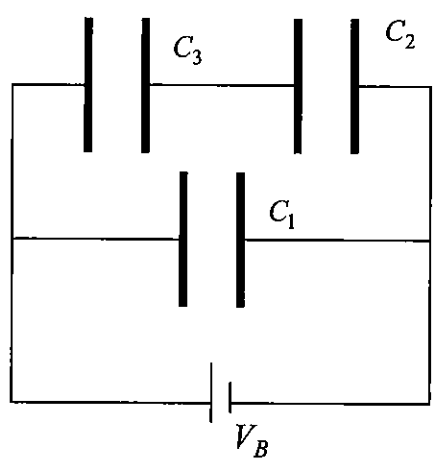

Figure 26

9. Which of the following is true for the connection shown in the figure?
   I. The magnitude of the charge on one plate of C_2 is the same as that on one plate of C_3.
   II. The potential drop across C_1 will equal the battery voltage.
   III. The magnitudes of the potential drops across C_2 and C_3 will add up to the drop across C_1.

   (A) I only (B) II only (C) III only (D) I and III only (E) I, II, and III

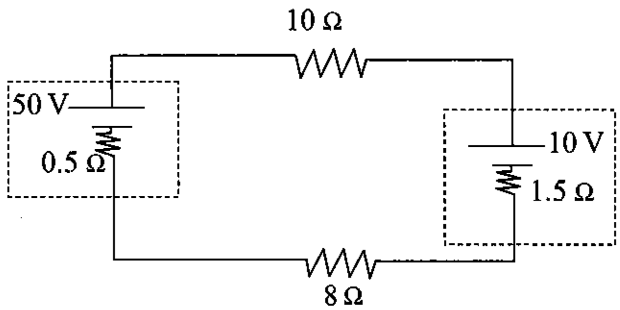

Figure 27

10. The batteries in the above circuit are contained within the dotted lines with internal resistances explicitly shown. The terminal voltage of the 10 V battery is

(A) 40 V (B) 60 V (C) 13 V (D) 7 V (E) 10 V

CHAPTER 12 PRACTICE EXERCISES

SECTION II FREE RESPONSE

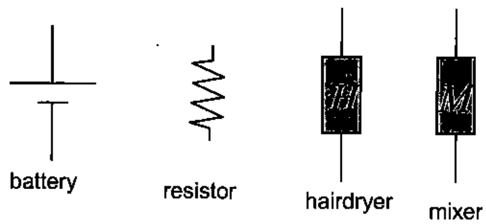

Figure 28

1. You are given a 120 V battery; a hairdryer designed to work properly at 120 V, where it's rated at 1,200 W; and a mixer designed to work properly at 60 V, where it's rated at 120 W. You also happen to have a large supply of 60 Ω resistors.
   (a) Determine the resistance of the hairdryer and the mixer at their rated voltages.
   (b) What current is established in the mixer when it's working properly?
   (c) Using the symbols shown in the figure, draw the connections needed to make both devices work simultaneously.
   (d) What power must the battery supply to run your circuit?

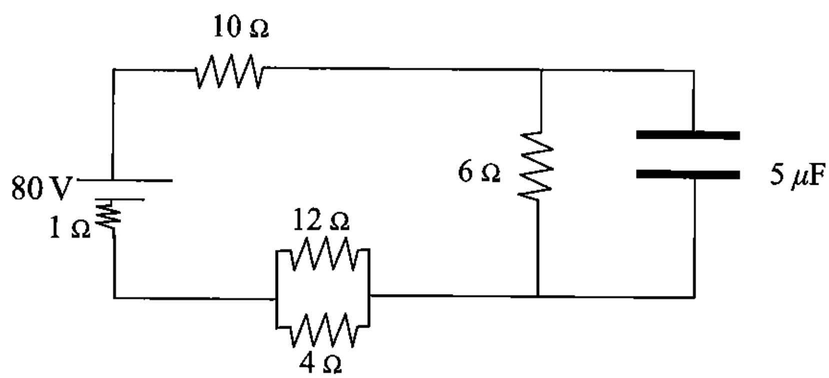

Figure 29

2. The circuit in the figure has been connected for a long time. The battery has an internal resistance of 1Ω.
   (a) Determine the terminal voltage of the battery.
   (b) Determine the current in the 4 Ω resistor.
   (c) What is the charge stored on one of the capacitor plates?
   (d) How long will it take for the 10 Ω resistor to consume as much energy from the circuit as is stored in the capacitor?

3. You are given a 9 V battery and three bulbs rated at respectively (9 V, 5 W), (9 V, 2 W), and (12 V, 6 W). Assume that the battery has negligible internal resistance and that the three bulbs obey Ohm's law and convert energy to light with equal efficiency.
   (a) When the 5 W bulb is connected to the battery terminals, what current will be established in the bulb?
   (b) What is the resistance of the 6 W bulb?
   (c) The 6 W bulb is connected to the battery terminals. How does its brightness compare to the 5 W bulb (a)? Explain.
   (d) The 5 W and the 2 W bulb are connected in series with the battery. Which bulb will be brighter? Explain.

Answers and Explanations

Multiple Choice

1. The answer is B. Each electron carries a charge of 1.6×10^{-19} C. The definition of current equation gives

$$i = \frac{\Delta q}{\Delta t} \Rightarrow 3.2 = \frac{N(1.6 \times 10^{-19})}{1} \quad \text{So } N = 2 \times 10^{19}$$

2. The answer is B. The series resistance is the sum of the two resistors, so the slope of V vs. I must be greater than either individual graph. The parallel resistance is less than the smallest resistance, in this case R_2, so the V vs. I graph must have a slope smaller than either individual graph.

3. The answer is D. The original resistance is $\rho\frac{L}{A}$. The second resistance will be $\rho'\frac{L'}{A'} = (2\rho)\frac{2L}{A'}$. Since the two resistances must be equal, $A' = 4$ A.

4. The answer is C. The equivalent resistance of the circuit is 16 Ω since the two parallel resistors give 4 Ω, so 2 A is drawn from the battery. All of this goes through the 12 Ω resistor, so using the loop law for the left loop gives you

$$+32 - (2)(12) - V_{6\Omega} = 0 \Rightarrow V_{6\Omega} = 8 \text{ V}$$

5. The answer is E. The energy supplied by the battery will equal the energy consumed by the resistors. Since the battery has 2 A established in it, the power supplied by the battery is

$$P = iV_B = (2)(32) = 64 \text{ W. In 10 s, 640 J is supplied.}$$

6. The answer is A. The junction law tells you that 3 A is present in R. Applying the loop law to the left loop, you have $50 - 3R - 20 = 0$, so $R = 10\ \Omega$.

7. The answer is B. $V_T = V_B \pm ir$, so the terminal voltage can be either greater than or less than the ideal voltage, depending on whether the battery is being recharged or is supplying energy to the circuit. This eliminates II and III. Since the current i depends on what is connected to the terminals, I is true.

8. The answer is B. After a long time, there will be no current in the capacitor branch, so the left loop has a single current established in it. Applying the loop law here gives you $30 - 10i - 5i = 0$, so $i = 2$ A. The capacitor is in parallel with the 5 Ω resistor, so its potential difference is $V_{cap} = V_{5\Omega} = (2)(5) = 10$ V. From the definition of capacitance, you have $Q = CV_{cap} = (2 \times 10^{-6})(10) = 20\ \mu C$.

9. The answer is E. Number I is true because series connected capacitors will have the same magnitude of charge on each plate; you can think of the battery as separating the charge of the extreme left and right plates. The inner plates will redistribute charge to create inner equipotential surfaces, which involves separating the same magnitude of charge here as well. The loop law tells you that II and III are true.

10. The answer is C. The overall resistance of the circuit is 20 Ω. Since the two batteries oppose each other, the effective battery voltage is 40 V. The current established in the circuit will be $i = \frac{40}{20} = 2$ A . Since the 10 V battery is recharging, the terminal voltage will be $V_T = 10 + (2)(1.5) = 13$V.

FREE RESPONSE

1. (a) You can use the power equation $P = \frac{V^2}{R}$ for each device, so

$$1{,}200 = \frac{(120)^2}{R_H} \qquad R_H = 12\ \Omega \qquad 120 = \frac{(60)^2}{R_M} \quad R_M = 30\ \Omega$$

(b) Use Ohm's law for the mixer.

$V = iR$

$60 = i(30) \Rightarrow i = 2$ A

(c)

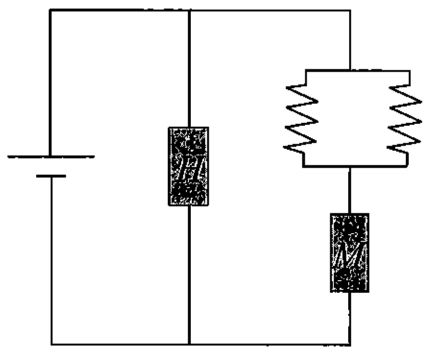

Figure 30

The hairdryer will be connected in parallel with the battery to get the needed 120 V potential difference. Since the mixer requires only 60 V, you must insert a resistor in series with it to lower the voltage drop. The resistor must have a voltage drop of 60 V as well so that the two add up to 120 V by the loop law. Since the current in the mixer is 2 A, Ohm's law says that the resistor must have a value $R = \frac{60}{2} = 30\ \Omega$. Two parallel 60 Ω resistors will do the job.

(d) The current in the hairdryer will be $i' = \frac{120}{12} = 10$ A. The junction law tells you that the total current established in the battery will then be 12 A, because there is 2 A in the mixer branch. The power supplied by the battery is

$$P = IV = (12)(120) = 1{,}440 \text{ W}$$

2. (a) After a long time, the capacitor will be fully charged. It could then be removed without changing anything in the battery-resistance part of the circuit, so you can analyze the latter as if the capacitor weren't present. The equivalent resistance of the circuit is 20 Ω since the two parallel resistors add to 3 Ω and the rest, including the internal resistance, are in series. The current established in the battery will be $i = \frac{80}{20} = 4$ A. The terminal voltage will be $V_T = V_B - ir = 80 - (4)(1) = 76$ V.

(b) The 4 A will divide at the junction of the 12 Ω and the 4 Ω resistors. If you assume a current x is established in the 12 Ω, then $3x$ will be in the 4 Ω. The junction law then says $x + 3x = 4$. Then $x = 1$ A, and the 4 Ω resistor will carry 3 A.

(c) The capacitor is in parallel with the 6 Ω resistor, so it will have the same potential difference across it. $V_{cap} = V_{6\Omega} = (4)(6) = 24$ V. From the definition of capacitance, you have $Q = CV_{cap} = (5 \times 10^{-6})(24) = 120\ \mu$C.

(d) The energy stored in the capacitor is

$$U = \frac{1}{2}CV_{cap}^2 = \frac{1}{2}(5 \times 10^{-6})(24)^2 = 1{,}440\ \mu\text{J}$$

The power dissipated in the 10 Ω resistor is

$$P = i^2R = 4^2(10) = 160\ \text{W}$$

Since watts are $\frac{\text{J}}{\text{s}}$, the time Δt must satisfy

$$P\Delta t = U$$

$$\Delta t = \frac{1{,}440 \times 10^{-6}}{160} = 9\ \mu\text{s}$$

3. A bulb will consume energy at its rated value only when the rated voltage is applied across it. At other applied voltages you will need to know the resistance of each bulb to determine the power consumed.
   (a) The 5 W bulb will consume 5 W when connected to the 9 V battery.

$$P = iV \Rightarrow i = \frac{5}{9} = 0.56\ \text{A}$$

(b) $P = iV = \frac{V^2}{R} \Rightarrow R_{bulb} = \frac{V^2}{P_{bulb}}$

$$R_{6\text{W}} = \frac{12^2}{6} = 24\ \Omega$$

(c) When connected to the 9 V battery, you can determine the power consumption from

$$P = \frac{V^2}{R} = \frac{9^2}{24} = 3.38\ \text{W}$$

This is less than 5 W, so the 6 W bulb will be dimmer than the 5 W bulb when connected directly to the 9 V battery.

(d) You can get the resistance of the 5 W and 2 W bulbs just as you did in (c).

$$R_{5\text{W}} = \frac{9^2}{5} = 16.2\ \Omega \qquad R_{2\text{W}} = \frac{9^2}{2} = 40.5\ \Omega$$

When connected in series with the 9 V battery, the current established in each bulb will be the same.

$$i = \frac{9}{16.2 + 40.5} = 0.16\ \text{A}$$

Since $P = i^2R$, the bulb with the greater resistance will be brighter. Thus the 2 W bulb will be brighter in this situation.